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J. Donalson del.

J. Haire sc.

A CONCISE
ESSAY ON MAGNETISM;

WITH
AN ACCOUNT OF THE DECLINATION AND INCLINATION

OF THE
MAGNETIC NEEDLE;

AND
AN ATTEMPT TO ASCERTAIN THE CAUSE OF
THE VARIATION THEREOF.

BY
JOHN LORIMER, M. D.

AND FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS OF EDINBURGH.

Veniet tempus quo ista quæ nunc latent, in lucem dies extrahet, et longioris ævi diligentia.—Tempus veniet quo posteri nostri tam aperta nos nesciisse mirentur.—SENECA NAT. QUEST. L. VII. c. 25.

L O N D O N :

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MAJESTY, the Corner of St. Martin's Lane.

M. DCC. XCV.



TO
HIS ROYAL HIGHNESS
THE DUKE OF CLARENCE,

THIS ESSAY ON MAGNETISM
IS,

BY PERMISSION,
HUMBLY INSCRIBED,

BY
HIS ROYAL HIGHNESS'S

MOST OBEDIENT AND

MOST HUMBLE SERVANT,

J. LORIMER.

A
SHORT HISTORICAL ACCOUNT
OF THE
DISCOVERY OF MAGNETISM,
AND OF THE
MAGNETIC NEEDLE.

Origin of
the name:

I. IT would be to little purpose at this time to inquire particularly whether the Magnet had its name from the shepherd Magnus, who, as Nicander and Pliny affirm, discovered it upon Mount Ida by the iron of his crook, and the nails in his shoes; or whether it was so titled from Magnesia, that part of Lydia, where, according to Lucretius, it was first found. The Grecians, indeed, who were acquainted with the various names it then went by, and likewise with its attractive property, have sometimes called it Siderites, from *σίδηρος*, iron; but more frequently the Heracleian stone, from the city Heraclea in Magnesia; and Snellius may be right in saying, that Euripides was the first who gave it the name of Magnes, though Sophocles called it *Lapis Lydius*.

2. With

Attractive
property.

2. With respect to the properties of the magnet, father Kircher endeavours to prove, that its attraction was known to the Hebrews; and from Plutarch it seems to appear, that the Egyptians were not ignorant of it. Pythagoras, Ptolemy, Hippocrates, Empedocles, Democritus, Leucippus, Epicurus, and many more of the ancients, knew and admired this wonderful property of the magnet. It was on account of this quality that Thales and Anaxagoras gave it a soul; and Plato, who called it the stone of Hercules, said, that the cause of its attraction was divine. Also Aristotle, Theophrastus, Dioscorides, Galen, and others amongst the ancients, have made particular mention of it.

Invention of
the mariner's
compass,

3. The discovery of the verticity or directive property of the magnet or loadstone, and the communication of that verticity to iron, or, in other words, the invention of the mariner's compass, though only a consequence of the former property, appears to be but of a modern date. It is indeed pretended, that the eastern nations were well acquainted with this property of the magnet, long before the Europeans had learned any thing about it. Some say that Solomon knew the use of the compass, and that thereby he was enabled to send his mariners to Peru, which was then called Parvaim

vaim and Ophir *. Other authors affirm, that the Chinese about that time, or even earlier than the days of Solomon, were acquainted with this most useful quality of the magnet. This, however, has been much doubted †,

Flavius Blond affirms, that in or about the year 1302, one John Goia, a noble citizen of Amalphi, a town of Principato, in the kingdom of Naples, first discovered the mariner's compass; and for this he quotes the following verse from Antony of Palermo, recorded by the Neapolitan historians; viz.

Primo dedit nautis usum magnetis Amalphi.

The arms of the territory of Principato has, it seems, ever since been a mariner's compass. It has also with equal confidence been asserted, that Marco Paulo, the Venetian, learned the use of the mariner's compass from the Chinese; and that he first made it known in Italy about the year 1260. But this cannot be true; for M. Paulo did not set out on his journey to China before the year 1269, nor did he return before the year 1295 ‡. It seems however from the documents, which will be ad-

* See Pineda de rebus Solomonis. L. iv. c. 15.

† See Du Hald's History of China, and the learned Renaudot's Dissertation on the Chinese Sciences, &c.

‡ See Purchase's Pilgrim, vol. III.

duced in the sequel, that the directive property of the magnet, and the communication of that property to iron, was known in Europe before this time; though to all probability it was not used in navigation till some time after; which may very reasonably be attributed to the clumsy way of suspending the magnetic needle, which was at first used*.

In the works of Claude Fauchet, entitled, *Recueil de l'origine de la Langue et Poésie François*, fol. 555, there is a quotation from an old French poem, called *la Bible Guiot*, in which the mariner's compass is evidently mentioned. This same passage is likewise quoted by Muschenbrock, in his *Dissertatio de Magnete*. The singularity of this passage having excited my curiosity, I made some enquiry after the above-mentioned old poem, in consequence of which, I found that there was a curious and interesting quarto manuscript of the 13th century, on vellum, in what was then justly called the Royal Library at Paris. The first article in this manuscript book, which was never published, is *la Bible Guiot*;

* The assertion of Dr. Wallis seems to be well founded; viz. that the magnetic needle, or compass, was brought to perfection by gradual steps and partial improvements, and that of these the English may claim considerable share.

the author of which, viz. *Guiot de Provins*, as mentioned in the poem itself, was at the court of the Emperor Frederic Barbarossa, held at Mentz in the year 1181, when the emperor's two sons were knighted*.

Here follows this remarkable passage, extracted from *la Bible Guiot*, in its original antiquated language, which has perhaps suffered much from the carelessness of transcribers, as may appear from the subjoined notes. The translation, which follows this passage, was made by a native of Provence, and as literal as possible.

* See Chron. Abbot. Ursperg. p. 311.

b

EXTRACT

EXTRACT FROM LA BIBLE GUIOT.

Iceille estoile ne se muet,
 Une arts font qui mentir ne puet,
 Par la vertu de la manete*
 Une pierre laide et brunete,
 Ou il fers volenters se joint. 5
 Ont regardent lor † droit point
 Puez c' une aguile lont touchie,
 Et en un festu lont fishie
 En longue ‡ la mette sens plus,
 Et il festui la tient defus; 10
 Puis se torne la point toute
 Contre lestoile sans doute,
 Quant il nuis est tenebre et brune
 Con ne voit estoile ne lune,
 Lor † font a laguille alumer; 15
 Puiz ne puent ils afforer,
 Contre lestoile vers la pointe;
 Par ce font § il mariner cointe,
 De la droite voie tenir;
 C'est uns ars qui ne puet mentir. 20

* Manete, magnete, magnes, the loadstone. This word is improperly written in different manuscripts; as *marinette*, *mariniere*, *mariniere*, &c. In the next line also, M. Fauchet has *noirette*, where it is *brunete* in my correspondent's manuscript.

† Lor, alors.

‡ An ingenious friend of mine observes, that *longue*, or *langue*, as some copies have it, may perhaps mean *Peau*; and in the same line *mette*, may have been *mettent*.

§ Ce sont, se sont.

LITERAL

LITERAL TRANSLATION OF THE PRECEDING.

This same (the pole) star does not move, (and)
 They (the mariners) have an art which cannot
 deceive,
 By the virtue of the magnet,
 An ugly brownish stone
 To which iron adheres of its own accord. 5
 Then they look for the right point,
 And when they have touched a needle (on it)
 And fixed it on a bit of straw
 Lengthwise in the middle, without more,
 And the straw keeps it above; 10
 Then the point turns just
 Against the star undoubtedly,
 When the night is dark and gloomy,
 That you can see neither star nor moon,
 Then they bring a light to the needle; 15
 Can they not then assure themselves
 Of the situation of the star towards the point (of
 the needle?)
 By this the mariner is enabled
 To keep the proper course;
 This an art which cannot deceive *. 20

* The expletive words, included in parenthesis in this translation,
 were thought necessary to make it the more intelligible, though they
 are not in the original; only in my correspondent's copy the second
 line runs thus:

Une arts font (les Marins) qui mentir ne puet.

Gaffendus adduces, as an argument of the French having been the inventors of the compass, that the north point thereof is always marked with a Flower de Luce*. As for Goropius's pretence, that the compass must be the invention of the Danes, Dutch, or Germans, because the thirty-two points on it are written, and pronounced in the Dutch or Teutonic language, has no better grounds than the English claim from the words Compass and Box †. Vincentius Belluacensis, and Albertus Magnus, who lived about the year 1245, as well as Livinus Lemnius, make mention of the direction of the poles of the magnet, as from a tract *de lapidibus*, which had been attributed to Aristotle, but is supposed to have been the work of some Arabian author, a little before, or about, their own time, which tract has been since lost.

Plautus in *Mercatore*, Act V. Scene II. has the following remarkable passage, viz. *Huc secundus ventus nunc est, cape modo vorforiam*. Now some authors will have it, that by the word *vorforiam* or *verforiam*, is meant the mariners compass; some learned critics, however,

* Lib. x. Diog. Laert. T. i. p. 139.

† It appears, however, that those nations were early acquainted with the use of the mariner's compass.

affirm,

affirm, that the word *versorium* meant a particular rope. For my part, I am inclined to believe that it meant nothing more than the helm.

The first Authors
on the verticity of
the magnet.

4. Francis Cabeus, a Jesuit of Ferrara, says, that the first thing he knows professedly wrote on the direction, or verticity, of the magnet, was an epistle of *Petrus Peregrinus Gallus*, about the latter end of the 13th century, and that the peregrinations of this same Peter, in magnetical philosophy, were not far from the truth. A few years after, this epistle was disguised by one John Tasnier, who published it in his own name, under the title of *Opusculum perpetua memoria dignissimum de natura et effectibus magnetis*. Some authors of note affirm, that this *Petrus Peregrinus* was no other than an assumed name of the English Friar Bacon, who flourished in the 13th century. By the favour of Mr. Senebier, I received the following account of the above-mentioned letter :

“ *Epistola Petri Peregrini de Marcourt, ad Sigerium
de Foucancourt, Militem de Magnete.*

“ The work contains a description of that stone, the
“ means of finding the poles, its property of attracting
“ iron, and proves that the part of the magnet, which
“ is turned to the north, attracts that which is turned to
“ the

“ the fourth. It then teaches the manner of employing
 “ the magnet in astronomy, and of playing tricks, like
 “ those of Comus. It deserves to be remarked, that the
 “ author knew not that the magnet could be employed
 “ in navigation; for, though he frequently speaks *de*
 “ *stella nautica*, he never speaks of the use that might be
 “ made of the magnetic needle in sea voyages.

“ *Vide Bibliotheca Bibliotecarum*, fol. II. p. 1400.
 “ Catalogue of the Manuscripts in the Library of Geneva,
 “ by Senebier, p. 207.”

Amongst the manuscripts of the university of Leyden, there is a volume containing many scientific tracts, one of which is a letter of Peter Adfiger, which is dated in the year 1269, and contains an account of almost all the properties of the magnet that are known at this day. The attraction, repulsion, directive property of the magnet, the communication of those properties to iron, the construction of the azimuth compass, the use of the magnetic needle and the variation of it, are clearly mentioned in this curious letter, which, in fact, is a concise Essay on Magnetism*.

* Ample extracts of this letter, which is entitled *Epistola Petri Adfigerii, in Signationibus Naturæ Magnetis*, have been published by Mr. Cavallo, in the second edition of his Treatise on Magnetism.

To give an account of all the numerous authors who have wrote on the properties of magnets, both natural and artificial, during the last and present centuries, would far exceed the brevity here intended; I shall, therefore, just add to those already mentioned the names of Des Cartes, Dr. Gilbert, Wm. Barlow, Peter Van Muschenbroeck, Savery, Dr. Knight, Mitchell, Canton, Paulus Frisius, Aepinus, and Cavallo. I have, indeed, heard of a laborious Italian Jesuit, by name Scarella, who some years ago published two quarto volumes on Magnetism, but I could never procure the book. It seems, that Dr. Knight had once proposed a work of the like extent on this subject; but he soon after laid aside all thoughts of publishing it.

I shall now proceed to give some account of the principal properties of the magnet, reserving the declination and variation of the needle for the latter part of this Essay.

A N
ESSAY ON MAGNETISM.

CHAPTER THE FIRST.

Of MAGNETISM in General.

Done at *New-York*, in the Year 1782, for a very ingenious young MIDSHIPMAN.

SECTION I.

A NATURAL magnet may not improperly be termed an iron ore; or rather a kind of native iron or virgin iron, as it is taken out of the earth. It resembles very much cast iron, and is endowed with the properties of attracting iron or other magnets (1). An artificial magnet is a piece of iron or steel, which has been endowed or impregnated with these same properties by art.

SECT. II. Every magnet, whether natural or artificial, has two principal points or poles, one whereof is called the North, and the other the South Pole. The similar poles of all magnets repel, and the dissimilar attract one another: that is, the north pole of one magnet repels the north pole of another, but it attracts the south pole, and *vice versa* (2).

B

SECT.

SECT. III. If a slender bar of prepared iron or steel be properly placed between the poles of a good magnet, and kept there for some time, it will acquire a certain degree of magnetism, or, in other words, it will become an artificial magnet (3).

SECT. IV. If a good magnet, natural or artificial, be made of a spherical form, in which case it is called a *Terrella*, or little earth, and a small piece of iron wire or needle is placed on its surface about midway between the two poles thereof, this needle will lie in the direction of a meridian, or rather parallel to the axis of the magnet; and, consequently, will direct one of its ends to the north, and the other to the south pole.

Further, if this little needle is moved along the surface of the magnet eastward or westward all round, it will keep the same ends directed to the poles respectively; but if the needle is moved toward either of the poles north or south, it will, besides keeping one of its ends directed towards that pole, begin to elevate itself on the end which is directed to the nearest pole, the more and more as it advances; so that when it has arrived at this pole, it will stand perpendicular upon it.

If again, the little needle is moved toward the other pole of the magnet, the end which was elevated becomes lower and lower with a kind of tremulous motion, till the needle is nearly midway between the two poles, when

it

it falls flat, and becomes parallel to the axis of the magnet as before; and if it is carried on towards this other pole, it raiseth itself gradually on the opposite end in the same manner, till it becomes also perpendicular upon that pole (4).

SECT. V. If a good magnet, natural or artificial, be made to float in quicksilver or on water, or be suspended in such a manner as to have little friction, one of its poles will direct itself towards the north, and the other towards the south pole nearly; also if it is in the northern hemisphere, (magnetically speaking) the north pole of the magnet will descend below the horizontal line, while the south pole is elevated above it; but if it is in the southern magnetic hemisphere, then the south pole of the magnet will descend below, and the north pole will be elevated above the horizontal line. In either case, the measure of this inclination will be various, according to the situation of the place; but the whole exactly similar to the experiments of the spherical magnet or terrella, and little needle, already mentioned (5).

SECT. VI. Upon any part of the surface of this globe, if a bar of prepared iron or steel be suspended nearly in the same direction that the needle or magnet, having a free and unconfined motion, arranges itself in; and if this bar is kept in the same position for some time, it will become an artificial magnet (6).

SECT. VII. From what has been said, we conclude, that the globe of this earth is strongly impregnated with magnetism; for, like another magnet, it will communicate a considerable degree of magnetic power to any bar of prepared iron or steel, which may be upon its surface, if it is kept in a certain position for some time (see Sect. VI.). Also, that all such masses of native or virgin iron, as are formed in the bowels of the earth, will be impregnated with this same general magnetic virtue, as well as the bar already mentioned.

Further, that any such wires or slender bars of iron impregnated with magnetism, which have a free and unconfined motion, will be arranged nearly in a northerly and southerly direction, as mentioned in Sect. V. by the magnetical power of the earth alone; and thence all the properties of the magnetic needle or mariners compass may be explained; the variation thereof only excepted.

SECT. VIII. I shall conclude this first chapter with observing, that as it is not intended for a system of magnetism, I have only mentioned here such leading principles as were necessary for explaining the declination and variation of the magnetic needle, which is to be the subject of the ensuing pages; yet I flatter myself, that whoever is thoroughly master of the principles here laid down, will very easily come to understand every other property of the magnet, though he has never before made that subject his peculiar study.

NOTES

NOTES AND ILLUSTRATIONS

P N

CHAPTER THE FIRST.

1. **T**HERE are many rich iron ores which neither are, nor in that state can they be impregnated with magnetism; the pure calces of iron cannot be rendered magnetical.

QUERE 1st.

Would it not therefore appear, that iron in its metallic form only is susceptible of magnetism? As iron and steel are better purified than the natural magnet, and can more easily be made into a proper form, so the artificial are generally stronger than the natural magnets.

The longer a magnet is in proportion to its breadth, and the broader it is in proportion to its thickness, *cæteris paribus*, the stronger it generally is.

QUERE 2d.

Would it not therefore appear, that magnetism acts in proportion to the surface, and not as the quantity of matter like gravity? The magnetical machine of the late Doctor Gowen, Knight, is a further proof of this article: See Phil. Transf. Vol. LXVI. Part 2d. Anno 1776.

2. There are several ways of shewing this property of magnets; the most convenient I take to be by the common compass, the needle of which is an artificial magnet. Take therefore another magnet and point to it, and it will be found, that the north end of the magnet will repel the north, but it will attract the south end of the needle.

Reverse the magnet, and the south end of the magnet will repel the south end of the needle, but it will attract the north end: and as often as you reverse the magnet, the needle will in like manner be reversed. But to those who are not much acquainted with this subject, the most convincing method of shewing the attraction as well as the repulsion of magnets, is by laying an artificial magnet in a little boat of light wood, or the like (see Plate II.); and setting it to float in a bowl of water, and pointing another magnet to it end to end.

3. I do not propose this as the best or only method of making artificial magnets; but I mentioned it here as a fact, for the sole purpose of explaining some matters which I have further to offer in this Essay.

4. To shew this experiment to advantage, as it is a very material one; besides the Terrella, it will be necessary to have a small glass tube, with a round bulb, like those which are used for thermometers; into which we drop

drop a bit of a fine sewing needle, not above two-tenths of an inch long, which being applied to the Terrella, as in Plate III. may be easily guided round it, as is directed in Sect. IV.

5. But to exhibit these two properties at once, the best method is to have an instrument constructed in the manner of a dipping needle, such as I contrived anno 1764. This machine, which I have called an Universal Magnetic Needle, or Observation Compass, is minutely described in the Philosophical Transactions, vol. LXV. anno 1775; but a delineation of that instrument, which was omitted in the Phil. Transf., will be found in Plate I. of this Essay.

6. If this is a bar of hardened steel, it will take a considerable time before it acquires any magnetical properties; but when it has once become magnetical, it will not lose it easily; nor can the poles thereof be reversed any other way, than by such means as would have given it magnetism originally, if it had none.

This, therefore, we call fixed magnetism. But if the bar is of soft iron, it takes no length of time to become magnetical; for, in the northern hemisphere, the moment you put such a bar in the proper position, (see Sect. VI.) the lower end of it becomes a north pole, and the upper end a south pole. (If it is in the southern he-

misphere the lower end is the south, and the upper end the north pole.) Reverse the ends of the bar, and the poles are accordingly reversed, as often as you repeat the experiment.

The magnetism of this bar is therefore said to be moveable, and almost every tongs or poker, with a common compass, is sufficient to shew the experiment, (see Plate IV.) but by being often heated and cooled, and by generally standing in a perpendicular position, if their magnetism should appear to be fixed, let the lower end be struck against the floor, or the stones of the chimney, and the poles will immediately be changed; a smart stroke of a hammer will have the same effect, and a shock of electricity will give magnetism even to steel. Several conjectures might be started from these experiments, which at present however we shall omit.

CHAPTER THE SECOND.

*Of the Declination of the Magnetic Needle, commonly called
the Variation of the Mariner's Compass.*

SECTION I.

FROM attentively considering the principles laid down and explained in the foregoing part of this Essay, we conclude, that as the globe of this earth is a great magnet, so like every other magnet it must have two points or poles, which will act upon any magnetic or compass needle, in the same manner that another magnet or terrella would do; that is, it will cause one end of it to be directed to one of its magnetic poles, and the other end of it to the other. See Part I. Sect. 2, 4, 5, 6, and 7*.

It is likewise evident, that, according to the position of these magnetic poles, the compass needle will be differently affected, and from thence we may deduce the following cases.

* But in this place it is proper to observe, that what we call the north magnetic pole of the earth, is in fact a south pole; or, in other words, it is a magnetic pole, contrary to that pole of the needle which is attracted by, or directed towards, the north pole of the earth; because the magnetic attraction takes place only between poles of different denominations: and for the same reason, what we call the south magnetic pole of the earth, is in fact a north pole.

C

CASE

CASE I.

If the magnetic poles of this earth had coincided with the true poles thereof, there could have been no declination or variation of the mariner's compass in any part of the world, (i. e.) if the earth is uniformly magnetical; for in that case the needle, in pointing to the magnetic poles, must always have pointed to the true poles also. This needle would therefore be necessarily directed along the course of the meridian, or, in other words, it would have no declination either to the east or west thereof.

CASE II. See PL. V.

If the magnetic poles were situated in the same meridian, and in opposite parallels upon that meridian which passes through the magnetic and true poles, from one of the magnetic poles to the other, and upon the opposite meridian all along, there could be no declination, for the reason mentioned in the former case: likewise, upon the equator there would be no declination; for though if one of the magnetic poles was only to act upon the needle, in passing along the equator to the distance of 90° in longitude east or west, the declination would increase; so that at 90° distance from the line of no declination, it would be equal to the angle contained between the mag-

I

netic

netic and the true poles; yet as the other magnetic pole in this case is always within the same distance of the needle, it will act upon the opposite end of it with equal force, and consequently will keep it parallel to itself all round the equator: but in going from the equator north or south, the declination will be increased, so as to be 180° on the little arcs or spaces of the meridian contained between the true and magnetic poles; which is the greatest possible declination in all cases whatsoever.

I have further to observe on this case, that the lines of no declination, including these arcs of 180° , form two great circles of the globe, along the meridian and the equator, crossing one another at right angles, and dividing the surface of the globe into four quarters, two in each hemisphere; the one hemisphere having west declination in the north, and east declination in the south half thereof. In the opposite hemisphere it is just the reverse, so that each of the arcs or semicircles of no declination have east declination on one side of them, and west declination on the other. The small arcs of 180° declination, which are between the true and magnetic poles, I reckon in all cases as part of the lines of no declination; for there indeed the needle conforms itself to the meridian as well as in the other parts of the circle, though its ends are reversed.

In short, as all the lines of declination, or Halleyan lines as they are very properly called, do coincide and terminate in the magnetic and true poles, so these

arcs of 180° are a kind of stopgaps, making with each of these lines, as in the present case, a curvilinear figure, returning into itself, which figures from 180° between the poles to 0° declination upon the equator, do each of them include a space larger than the other, till at last they fill up the whole quarter of the surface of the globe, and conform themselves as nearly as possible to the shape and figure thereof. (See the Plate.) As a variety of this case I have just to mention, that the magnetic poles may be situated in the same meridian, but in parallels which are not opposite. In that case, the only alteration which could happen is, that in the hemisphere in which the magnetic and the true poles are nearest to one another, the figures formed by the Halleyan lines become smaller, and the corresponding figures in the opposite hemisphere, larger.

The line of no declination, which in this case represents the equator, would also be proportionably nearer to the poles which are nearest one another.

CASE III. See PL. V.

If the magnetic poles were situated in opposite meridians and opposite parallels, upon those meridians which pass through the magnetic and true poles, there could be no declination, for the reasons mentioned in the former cases. But upon the equator eastward and westward to the distance of 90° in longitude, the declination would actually increase, so as there to be equal to
 2 the

the angle which measures the distance between the true and magnetic poles, and from thence would in the same manner decrease for the other 90° to the opposite meridian.

The Halleyan lines of 10° , 20° , &c. as far as the greatest declination upon the equator, in this case become arcs or curves, which conform themselves as nearly as may be to the course and direction of the lines of no declination, and are called by Magnetists the lines of the first order; but the lines of the greatest equatorial declination cross one another at the distance of 90° in longitude, from the meridian or circle of no declination, something in form like the letter X, or like to two Gothic arches joined at the vertex. They are termed lines of the second order, and may very properly be considered as the boundary between the lines of the first and third order; as the lines of no declination are always boundaries between the lines of the east and west declination. In this case these lines of no declination, including the arcs of 180° , form only one great circle along the meridian, dividing the surface of this globe into two hemispheres; in the one of which there is east declination, and in the other, west declination.

From the greatest equatorial declination to the arcs of 180° , the Halleyan lines of the third order, are curves returning into themselves, and in shape nearly resembling parabolas, erected upon the arcs of 180° . As a variety of this case also, I have only to add, that if the magnetic

netic poles were situated in opposite meridians, but in parallels which are not opposite, then in that hemisphere, in which the true and the magnetic poles approach nearest to one another, the figures formed by the Halleyan lines would be smaller, and in the opposite hemisphere the corresponding figures would be larger in proportion.

It was once the general opinion, that the poles of every magnet must be diametrically opposite to one another, as the poles of natural magnets are generally found to be so; but Doctor Gowen Knight has demonstrated by experiments, that the poles of magnets may be disposed in every possible direction. See Phil. Trans. N^o 474, 476, 484, &c. Anno 1744, 1746, 1747. (See the Plate.)

C A S E IV. See P L. VI.

I have only one case more to mention, but it is a very extensive one; viz.

When the magnetic poles are situated neither in the same nor opposite meridians: and this seems to have been the real position of these poles, ever since any observations of the declination of the magnetic needle have been made.

In this case, then, the lines of no declination cannot be either in the direction of the meridian or along the equator, as in the former cases; but a kind of curves
which

which are variously inclined to both, and they divide the surface of this globe into two parts; but these parts are not hemispheres, as in the last case; for they may be of very different extent.

If the magnetic poles are situated in meridians nearly opposite, the curvatures of those lines are the less: that is, they become more like to Case 3d. But as the magnetic poles approach nearer to the same meridian, the curvature of the lines of no declination become greater till they almost touch one another, something in form like the figure 8; and at last they complete the two great circles, as in Case 2d.

The lines of the second order, which correspond to the greatest equatorial declination, if the magnetic poles are situated in meridians nearly opposite, have a declination nearly equal to the angle formed between the magnetic and true poles, as in Case 3d.

But as the magnetic poles approach toward the same meridian this declination decreases, till at last it entirely vanishes; together with the lines of the first order; and, as in Case 2d, leaving only the lines of the third order.

The other Halleyan lines in this case are so similar to the former, that they require only to be referred to it.

I have therefore just to add, that whether the magnetic poles are situated in opposite parallels or not, makes as little difference in this case as in the former. (See the Plate.)

SECT. II. Though I flatter myself, that the foregoing pages will be found to contain all the cases that are necessary toward an explanation of the declination of the magnetic needle, at any one time; yet to those who wish to be acquainted with this curious subject more fully, I would beg leave to recommend Mr. Euler's Researches, in the Berlin Memoirs for the Year 1757, a performance which will give some satisfaction even to those who cannot enter into all his mathematical calculations; but for the convenience of such gentlemen as may not soon have it in their power to consult that volume, and as an example of the fourth Case, I shall transcribe from Mr. Euler's Map, annexed to the paper above-mentioned, the state of Magnetism about the middle of this century. According to this ingenious author, the North Magnetic Pole seems then to have been situated near to the meridian, which passes by Cape St. Lucar, the South Point of California, and between the latitudes of 70° and 80° North.

(I do not think the observations are as yet sufficient to authorise our being very particular*.)

The situation of the South Magnetic Pole, at that time, seems to have been above 60° more Westwardly, and near the latitude of 60° South†.

* Mr. Euler says 73° or 76° . † According to the same Author 55° .

SECT. III. From this position of the magnetic poles then, the result is as follows. From the north magnetic pole a line of no declination commences, and by a route somewhat resembling the letter S, it traverses the continent of North America and the Atlantic Ocean, &c. to the south pole of the earth, and then, by the arc of 180° to the south magnetic pole.

From the south magnetic pole this line of no declination proceeds, and in like manner traversing the Pacific Ocean, passes by the islands of the East Indies, and through the continent of Asia to the north pole of this earth, and so by the little arc of 180° to the north magnetic pole.

These lines divide the surface of this globe into two parts; and in going eastward from the first to the second line, over the eastern parts of North America, Europe, Africa, and a great part of Asia, there is west declination; but from the second to the first, over the eastern parts of Asia, South America, the western parts of North America, and the Pacific Ocean, there is east declination. The declination of the lines of the second order, corresponding to the greatest equatorial declination, amounts in this case to 12° , and for the east declination they cross one another in north latitude 24° , and about 30° in longitude west of the meridian of California: for west declination the intersection is likewise in 24° north latitude, upon that part of the coast of the Red Sea, which is next to Arabia Felix.

If any person will take the pains to compare this with the charts of Messrs. Mountain and Dodson for 1744 and 1756, he will find a surprizing similitude; and from what has been said, with the help of these charts upon a common map of the globe, all the Halleyan lines may be drawn by hand. I have been the more particular on this part, as it is possible that each of these positions of the magnetic poles may have been, or hereafter may happen to be, their real situation; and as it is evident, that the fourth Case has been their position ever since any observations have been made on that subject, so it is probable that it will continue to be their situation for many ages to come. I shall therefore conclude this second chapter, by observing, that if in some instances our best observations should not perfectly agree with calculations, we are not therefore entirely to reject the theory; for, supposing the observations to be perfectly exact, which is not always the case, yet as this earth is undoubtedly a very heterogeneous body, it may not be uniformly magnetical, as should be the case, if it was to agree entirely with the calculations, &c.

CHAPTER

CHAPTER THE THIRD.

FROM what has been said in the two preceding chapters, we may conclude, 1st. That the earth is a great magnet, endowed with all the properties which have been observed in common magnets; 2dly, That the magnetic needle owes its directive property to the vicinity of this great magnet, in the same manner as we have shewn to happen with a small needle, when placed upon a *terrella*, or globular magnet; and 3dly, That the direction of the needle must either coincide with, or deviate from, the meridian, according as the magnetic poles of the earth happen to be situated. After this, it will be necessary to examine the real state of the matter; namely, to consider, according to the best observations, the lines of declination throughout the world, a summary view of which will be contained in the present chapter.

SECTION I. That line, which I shall call the Atlantic line of no declination, seems to take its origin from the north magnetic pole, and crossing the different meridians in a south-easterly direction, resembling in form the long letter S, it traverses the continent of North America, enters the Atlantic Ocean to the northward of Charlestown, and so proceeds towards the south pole. Upon

the west side of this line there is east declination, and upon the east side thereof, west declination; which last gradually increases as you go to the eastward, till you get beyond the Cape of Good Hope, or about midway between the Atlantic and the East India line of no declination, where it amounts to 31° , about the latitude of 48° south, and then it regularly decreases to the East India line of no declination.

Again, as you go to the eastward of that line of no declination, the east declination increases rapidly till you get to the eastward of New Zealand, where it is upwards of 13° even in that latitude; but from thence, as you proceed eastward, for about 40° in longitude, this declination appears to decrease; and again, it increases till you are to the eastward of Cape Horn, where, in the latitude of 51° south, it amounts to $21^{\circ} 28'$, and then gradually decreases to the Atlantic line of no declination aforesaid. Upon the whole it would appear, that these observations agree pretty nearly with the fourth general case described in the preceding chapter, except in that decreasing east declination to the eastward of New Zealand. But admitting that the vast body of water in the great Pacific Ocean, which cannot have any magnetic properties, should have no effect in producing this irregularity, yet we are not to expect even that the solid parts of this globe can be so uniformly magnetical throughout, as to answer entirely with calculation in every part thereof.

SECT.

SECT. II. The magnetic needle not only declines, or varies from the true north, differently in different parts of the earth at any one time, but likewise in the same place this declination is different at different times; I would therefore call it, by way of distinction, the variation of the magnetic needle.

SECT. III. At London and Paris, where the most accurate observations have been made, towards the latter end of the sixteenth century (and we cannot pretend to much earlier observations) there was between 11° and 12° of east declination, which gradually decreased; so that in less than a hundred years afterwards, there was no declination at all in those places. From 1657, at London, and 1666, at Paris, a west declination began, and has ever since increased gradually, though not uniformly, or in the direct proportion of the times; for such is the nature of the magnetic declination, that, like the apparent motion of the planets, sometimes it is faster, sometimes slower, at other times it is stationary; analogous also to the elongations of the inferior planets, at one time it is to the east, and at another time to the west, alternately.

We may farther observe, that the declination lines of the same name have always respectively passed London some years before the same lines arrived at Paris; and the like observations have been made in other parts of the northern hemisphere, that is, in this hemisphere
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the Halleyan lines have regularly passed those places first which lay most westerly, and so in order, those which lay more to the eastward. For in the latter end of the sixteenth century, there was an eastern declination over most parts of Europe, while on the coast of North America a west declination prevailed; the line of no declination being then situated about the Azores. This line of no declination has ever since moved gradually eastward, the lines of east declination receding before it, while the lines of the west declination have gradually followed it.

SECT. IV. In the southern hemisphere, however, it is quite otherwise; for about the latter end of the sixteenth century, a line of no declination passed near to the Cape of Good Hope, upon the east side of which there was west declination, and upon the west side thereof east declination; each of which declinations, in going eastward or westward, gradually increased to a certain degree, and then in the same manner decreased to nothing, somewhere to the eastward of Java, one of the East India islands.

The declination in the Pacific Ocean has not as yet (1775) been so fully ascertained, only in general we find, that the declination is easterly over most part of that extensive ocean. The line of no declination, which was then situated a little to the eastward of the Cape of Good Hope, has ever since been moving to the westward,
and

and the lines of east declination have gradually receded before it, while those of the west declination have followed it with a proportional pace; so that at the Cape of Good Hope there is now a considerable west declination (about 24° *) and the line of no declination has moved many degrees to the westward thereof.

SECT. V. From the preceding observations then it plainly appears, that the Halleyan lines in the southern hemisphere do gradually move from east to west, while the motion of those lines in the northern hemisphere is from west to east; and here we shall rest the matter for the present.

I shall just beg leave to observe, that in treating of this subject, I have all along only endeavoured to explain the manner in which magnetism acts upon this globe; yet if the preceding conclusion be admitted, viz. that the progressive motion of the lines of declination in the northern hemisphere is constantly from west to east, and in the southern hemisphere from east to west, this discovery will be of as great use to us in framing, regulating, or judging of our future charts or tables of the declination or variation of the mariner's compass, and will answer the purposes of navigation as well, as if we were thoroughly acquainted with the primary causes of all the phenomena of magnetism.

* The author received this and other informations from Colonel Gordon, commander of the Dutch forces at the Cape.

CHAPTER THE FOURTH.

*An Attempt to explain the Cause of the Variation of the
Magnetic Needle.*

WROTE IN THE YEAR 1793.

——— Si quid novisti rectius istis,
Candidus imperti : si non, his utere mecum.

Horat. Epist. VI. lib. 1.

SECTION I.

IF we were to enter into the history of magnetism, the discovery of the mariner's compass, or even that curious subject the declination or variation of the magnetic needle, we should find that the compass was known probably before the year 1181, and the variation at least as early as the month of August, 1269*, though that subject was not brought to any kind of regularity till the time of Dr. Halley. The researches and observations of that ingenious gentleman have been of the utmost service in navigation, however whimsical his theory may have appeared to some people.—But this for the present we pass over.

* See the Edinburgh periodical publication, entitled, *The Bee*, vol. xiii. N^o 3. Columbus observed the variation of the compass in his first voyage, anno 1492.—Musschenbrek de Magnete, Exp. 97.

SECT. II. On the principles of the ingenious Mr. Euler (see the Berlin Acts, volume for the year 1757) the declination of the magnetic needle may in great measure be accounted for. That is, supposing the magnetic poles of this earth to be, at any one time since actual observations have been made on that subject, only two, but not situated diametrically opposite to each other. (See Cavallo's Treatise on Magnetism, p. 117.) It is also well known that the magnetic declination is not only different in different parts of the earth at the same time, but that in a course of years it also becomes different in the same place. Farther, that this declination in the same place is not only different in different years, but even the afternoon declination is generally different from the forenoon declination of the same day.

SECT. III. This subject appeared very unaccountable till the year 1759, when the late Mr. John Canton explained it in a very ingenious manner; for having found by experiment, that by heating a magnet it lost part of its attractive power, and by letting it cool, it recovered that power again; he likewise discovered by repeated observations, that while the eastern parts of the earth were heated by the sun in the forenoon, and consequently had their magnetic powers diminished, the needle generally inclined more to the westward, and that after the sun had passed our meridian, and the western parts

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of

of the earth began to be heated, while those on the east of the meridian were cooled, the declination of the needle was less westerly by several minutes, and that by next morning it had returned to its former position nearly.—We say nearly, for after a course of more than twelve months attentive observation he found, that the declination was upon the whole increased of about ten or twelve minutes of a degree. That this increase was occasioned by the sun's heat, appeared the more probable, as it took place mostly in the summer months; and during the winter months there was but little alteration, as appears from the following table * :

The mean difference of diurnal variation for each month in the year 1759.

January	-	-	7.	8."	July	-	-	13.	14."
February	-	-	8.	58.	August	-	-	12.	19.
March	-	-	11.	17.	September	-	-	11.	43.
April	-	-	12.	26.	October	-	-	10.	36.
May	-	-	13.	0.	November	-	-	8.	9.
June	-	-	13.	21.	December	-	-	6.	58.

SECT.

* Mr. Canton, it seems, made in 603 days about 4000 observations on the subject, with an excellent variation compass about nine inches in diameter. In 574 of those days the variation was regular, and consequently only 29 irregular, according to his system. Mr. Canton's opinion was, that when the variation increases from about eight or nine o'clock in the morning till one or two in the afternoon, then becoming stationary

SECT. IV. It must be allowed, according to the observations of several ingenious gentlemen, that the collective magnetism of this earth arises from the magnetism of all the ferruginous bodies therein contained, and that the magnetic poles should therefore be considered as the centres of the powers of those magnetic substances. These poles must therefore change their places according as the magnetism of such substances is affected; and if with Mr. Canton we allow that the general cause of the diurnal variation arises from the sun's heat in the forenoon and afternoon of the same day, it will naturally occur, that the same cause, being continued, may be sufficient to produce the general variation of the magnetic needle for any number of years. For we must consider that ever since any attentive observations have been made on this subject, the natural direction of the magnetic needle in Europe has been constantly moving, from west to east, and that in other parts of the world it has continued its motion with equal constancy.

for some time, after that returning back again to its former station in the night, or by next morning, it is regular. But he calls it irregular when the needle moves eastward in the hotter part of the morning, or westward in the latter part of the afternoon; also when it moves either way in the night, or suddenly, viz. when it moves both ways in a short space of time. The causes of those irregularities he attributes to subterraneous heat, to the Aurora Borealis, &c.

SECT. V. As we must therefore admit that the heat in the different seasons depends chiefly on the sun, and upon the whole that the months of July and August will probably be found the hottest, while January and February are the coldest months of the year; and that the temperature of the other months falls into the respective intermediate degrees; though from calculation we can scarce pretend to ascertain the absolute heat of any particular month or day; so we must consider the influence of heat upon magnetism to operate in the like manner, viz. that for a short time it scarcely manifests itself; yet in the course of a century, the constancy and regularity thereof becomes sufficiently apparent. It would therefore be idle to suppose, that such an influence could be derived from an uncertain or fortuitous cause. But if it be allowed to depend upon the constancy of the sun's motion *, and this appears to be a cause sufficient to explain the phenomena, we should (agreeably to Newton's first law of philosophizing) look no farther.

SECT. VI. As we therefore consider the magnetic powers of the earth to be concentrated in the magnetic poles, and that there is a diurnal variation of the magnetic needle, these poles must perform a small diurnal revolution proportional to such variation, and return again to

* See Dr. John Hunter on Heat, Phil. Transf. for 1788.

the same point nearly.—Suppose then that the sun in his diurnal revolution passes along the northern tropic, or along any parallel of latitude between it and the æquator, when he comes to that meridian in which the magnetic pole is situated, he will be much nearer to it, than in any other; and in the opposite meridian he will of course be the farthest from it. As the influence of the sun's heat will therefore act most powerfully at the least, and less forcibly at the greatest distance, the magnetic pole will consequently describe a figure something of the elliptical kind; and as it is well known that the greatest heat of the day is some time after the sun has passed the meridian, the longest axis of this elliptical figure will lie north-easterly in the northern, and south-easterly in the southern hemisphere. Again, as the influence of the sun's heat will not from those quarters have so much power, the magnetic poles cannot be moved back to the very same point, from which they set out; but to one which will be a little more northerly and easterly, or more southerly and easterly, according to the hemispheres in which they are situated. The figures therefore which they describe, may more properly be termed elliptoidal spirals*.

* The north magnetic pole may by this means be carried, with a slow but constant motion, more and more to the north eastward, till it arrives at the region of the greatest cold, which, by the bye, is supposed to be at some degrees distance from the natural pole of the earth. And likewise the other magnetic pole will be carried, &c.

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SECT.

SECT. VII. In this manner the variation of the magnetic needle in the northern hemisphere may be accounted for. But with respect to the southern hemisphere we must recollect, that though the lines of declination in the northern hemisphere have constantly moved from west to east, yet in the southern hemisphere, it is equally certain that they have moved from east to west, ever since any observations have been made on the subject*. Is it possible then that the magnetic pole in the southern hemisphere can move from east to west, whilst that in the northern hemisphere moves from west to east?—I think not. But we must consider this matter a little more attentively. In the first place it must be observed, that in speaking of the declination or variation of the magnetic needle, we always refer to the north end of the needle only. Thus, when the north end of the needle points to the west of the meridian, we say it has so many degrees west variation, though the south end thereof points as many degrees to the eastward. Again, when the north end of the needle points to the eastward of the meridian, we say it has east variation, though the south end points to the westward thereof. And the same language is used in the southern as in the northern hemisphere; so that if the south magnetic pole, which governs the needle in that hemisphere, move to the eastward, oc-

* See Cavallo's Treatise on Magnetism.

ractions, as we say, the needle to have west variation; and, on the contrary, if it move to the westward, it makes what we term east variation. This therefore is the cause, on account of which the lines of magnetic declination, or Halleyan curves, as they are now commonly called, appear to have a contrary motion in the southern hemisphere, to what they have in the northern; though both the magnetic poles of the earth move in the same direction, that is from west to east*.

SECT. VIII. This might be made still more evident by a diagram, or by means of the mariner's compass and a common magnet: and here we might rest the matter for the present, but I cannot help mentioning the idea of Dr. Gower Knight, a gentleman undoubtedly known to have

* In the northern hemisphere there was a line of no variation, which had east variation on its eastern side, and west variation on its western side. This line evidently moved from west to east, during the two last centuries; the lines of east variation moving before it, while the lines of west variation followed it with a proportional pace. These lines first passed the Azores or Western Islands, then the meridian of London, and after a certain number of years still later, they passed the meridian of Paris. But in the southern hemisphere there was another line of no variation, which had east variation on its western, and west variation on its eastern side; the lines of east variation moving before it, while those of the west variation followed it. This line of no variation first passed the Cape des Aiguilles, and then the Cape of Good Hope; the lines of 5° , 10° , 15° , and 20° , west variation following it, the same as was the case in the northern hemisphere, but in contrary direction.

been

been well acquainted with practical as well as theoretical magnetism. His opinion was, that this earth had originally received its magnetism, or rather that its magnetical powers had been brought into action, by a shock, which entered at about the southern, and passed out at the northern tropic. His meaning appears to have been, that this was the course of the magnetic fluid, and that the magnetic poles were at first diametrically opposite to each other.

SECT. IX. In this Essay our intention has all along been to avoid suppositions merely theoretical; for we do not pretend to explain the causes of magnetism on any theory however plausible. Yet we have no objection to Dr. Knight's supposition, that the magnetic poles might at first have been opposite to each other; though, according to Mr. Canton's doctrine, they would not have long continued so; for from the intense heat of the sun in the torrid zone, according to the principles already explained, the north pole must have soon retired to the north-eastward, and the south pole to the south-eastward. It is also curious to observe, that on account of the southern hemisphere being colder upon the whole than the northern hemisphere*, the magnetic poles would have moved with

* It is well known that in the course of the year the sun is for about eight days longer in the northern than in the southern hemisphere; but without entering into all the causes of this effect, it is here sufficient to observe that this fact has been indisputably proved.

unequal

unequal pace; that is, the north magnetic pole would have moved farther in any given time to the north-east, than the south magnetic pole could have moved to the south-east. And, according to the opinions of the most ingenious authors on this subject, it is generally allowed, that at this time the north magnetic pole is considerably nearer to the north pole of the earth, than the south magnetic pole is to the south pole of the earth.

Charlotte Street, Sept. 30, 1794.

P. S. Several ingenious sea officers are of opinion, that in the western parts of the English Channel the variation of the magnetic needle has already begun to decrease; having in no part of it ever amounted to 25° . There are, however, other persons who assert, that the variation is still increasing in the Channel, and as far westward as the 15th degree of longitude and 51° of latitude, at which place they say that it amounts to about 30° .

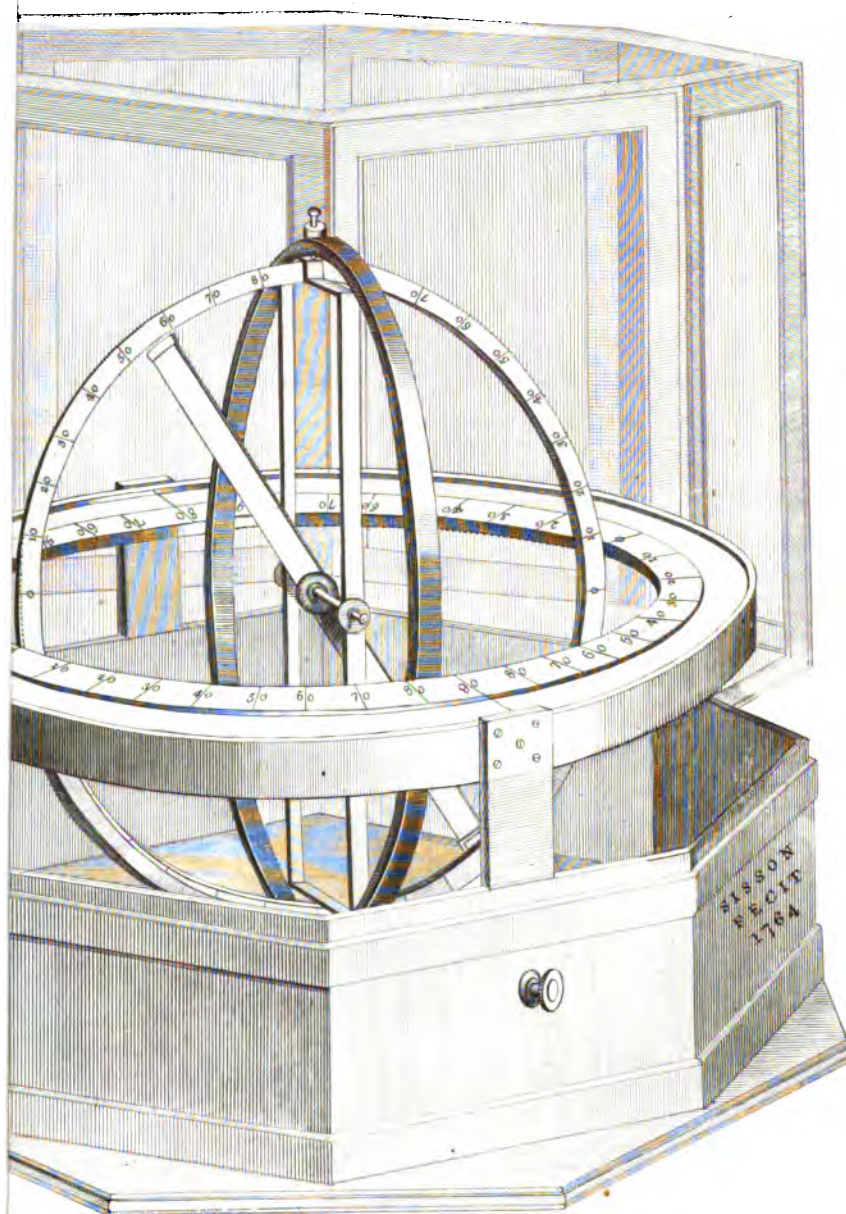
AN
EXTRACT
OF A
LETTER

From the ingenious Dr. NOOTH, to the AUTHOR.

Dated Quebec, Nov. 1st, 1793.

AS I am well convinced, that you will with pleasure receive any communication respecting the magnetic influence, I shall just tell you, that lately I accidentally found that there was a diminution in the variation of this place since the year 1785. In that year Major Williams and Major Holland, ran a meridian on the plains of Abraham; and on the several stones that were placed in the line of the meridian they marked the longitude, latitude, and variation. At that time the variation, by the mean of many compasses, was $12^{\circ} 35'$; at present I find it only $12^{\circ} 5'$; and this has been ascertained by at least thirty needles, so that there can be no doubt of the fact.

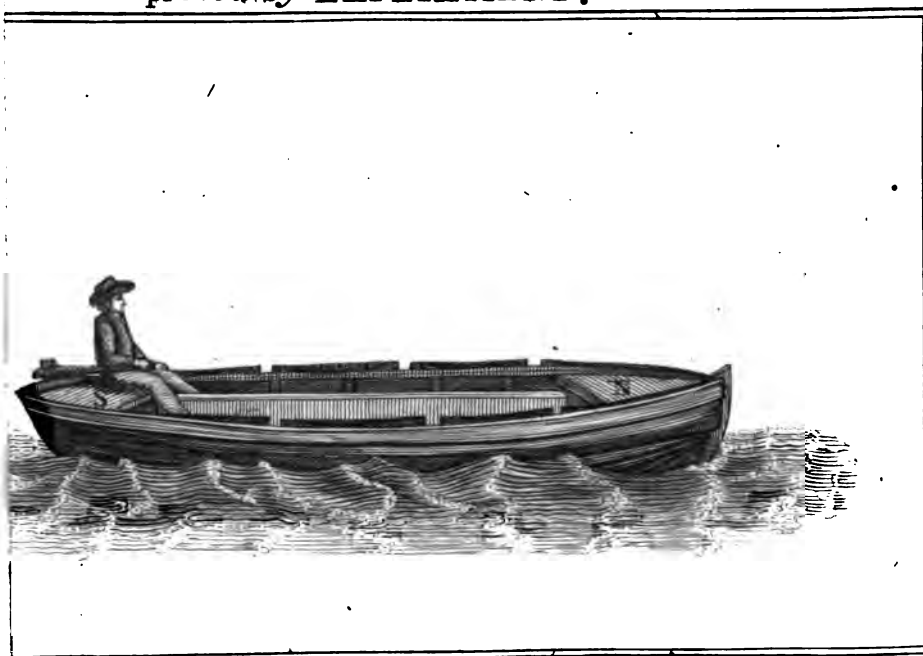
THE END.



Needle by John Lorimer M.D. See the Philos. Trans Vol. LXV.

PRINCIPAL PROPERTIES of the MAGNET
proved by EXPERIMENT.

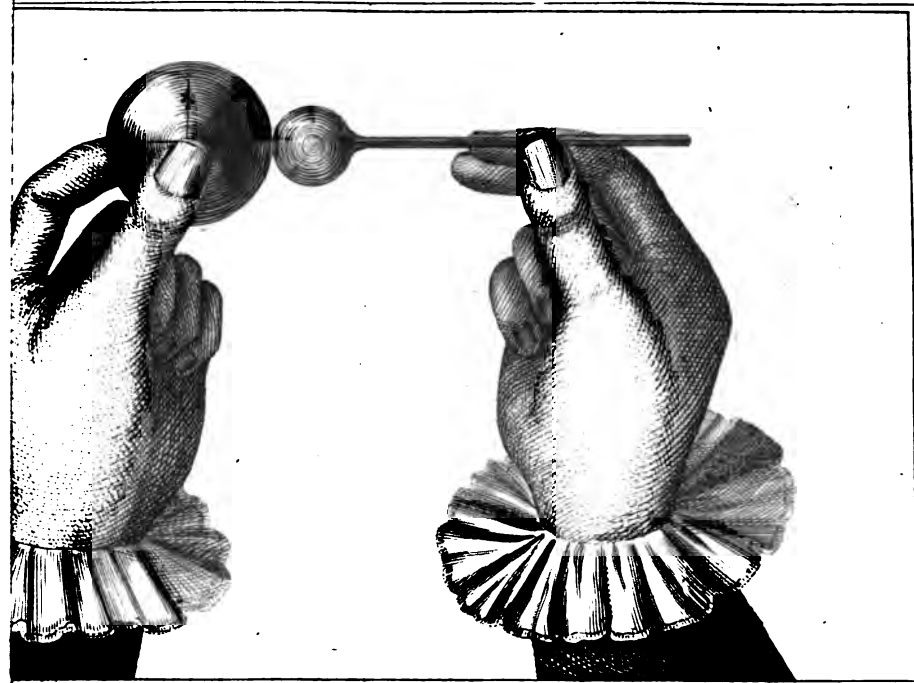
Pl. II.

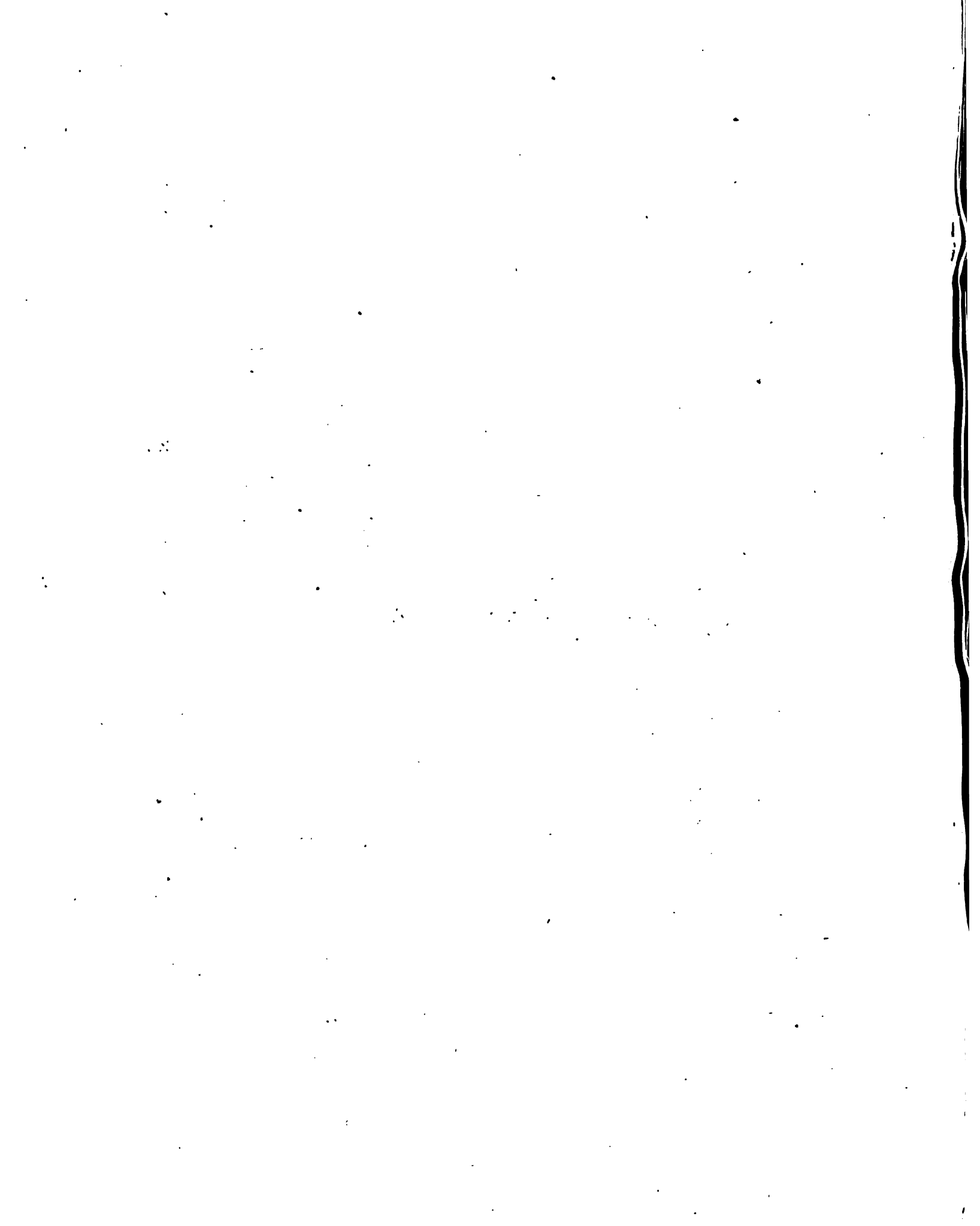


Longman & Co.

The PROPERTIES of the TERRELLA.

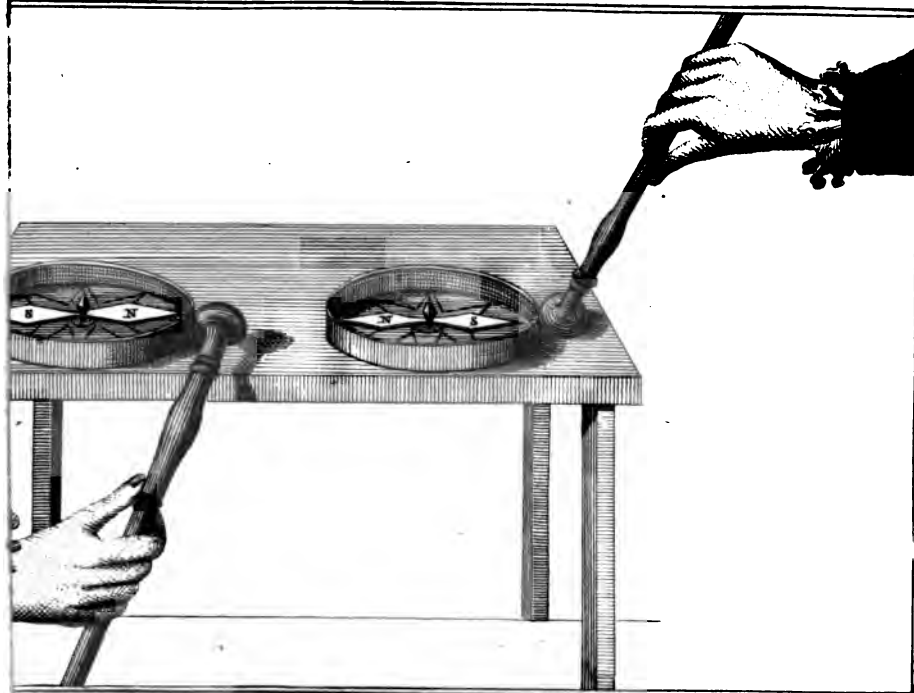
Pl. III.





MAGNETISM of the EARTH proved by SOFT IRON.

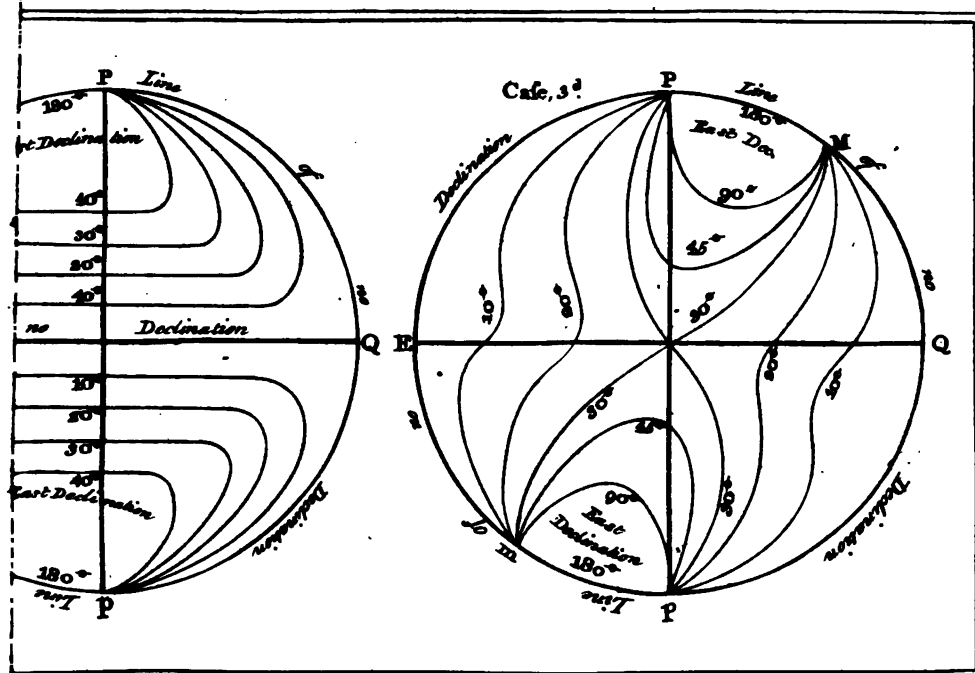
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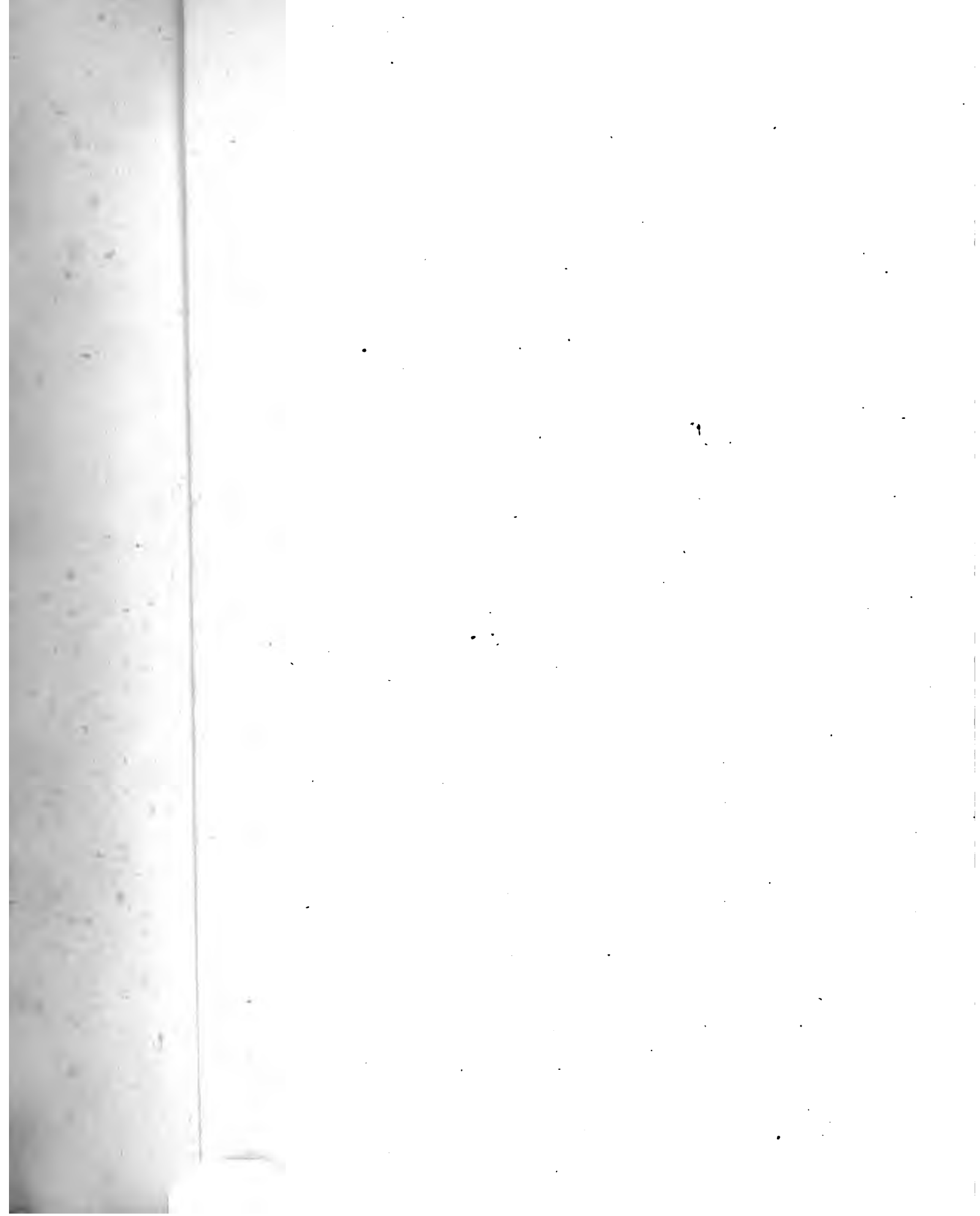


Longstaffe sculp.

LINES OF MAGNETIC DECLINATION.

Pl. V.





II. LINES of the MAGNETIC DECLINATION or VARIATION.

Pl. VII.

